Socioeconomic and Selected Behavioral Determinants as Risk Factors for Dental Caries throughout the Life Span

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ABSTRACT

Objectives: The Surgeon General's report on oral health as well as other reviews conclude that socioeconomic status (SES) is significantly related to oral health, with those in the lower segments of society being at greatest risk for craniofacial diseases and conditions. This premise appears to hold for dental caries incidence and prevalence among both children and adults. However, no evidenced based systematic reviews of these relationships have been conducted and these premises are based largely on selective reviews of the literature. This paper systematically reviews reports on the relationship between socioeconomic status and the incidence and prevalence of dental caries for children and adults, and based on pre-established criteria, evaluates the quality of the papers reviewed and synthesizes results based on these studies. Additionally, this paper evaluates the literature on the importance of two behavioral risk factors tooth brushing and infant feeding practices that may partially explain any identified SES differences in the risk of caries

Focused Questions*:* This review has 8 focused questions: 1) Are children less than six years of age with primary teeth and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status? 2) Are children ages six to 11 with mixed dentition and of lower socioeconomic status at increase risk of dental caries compared with children of the same age and dentition of higher socioeconomic status? 3) Are children ages 12-17 with permanent teeth and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status? 4) Are adults ages 18-64 and of lower socioeconomic status at increased risk of dental caries compared with adults of the same age of higher socioeconomic status? 5) Are adults ages 65 and older and of lower socioeconomic status at increased risk of dental caries compared with adults of the same age of higher socioeconomic status? 6) Are children ages less than 18 who do not brush their teeth one or more times daily at increased risk of dental caries compared with children of the same age who do brush daily? 7) Are adults ages 18 and

over who do not brush their teeth one or more times daily at increased risk of dental caries compared with adults of the same age who do brush daily? 8) Are children over the age of 12 months who continue to use a baby bottle once or more a day at increased risk of dental caries compared with children of the same age who no longer use a baby bottle?

***Search Strategy**:* NIDCR contracted for a consultant to construct the search terms and to search the literature in two databases, Medline and EmBase. Limitations of resources precluded hand searching or a search of unpublished studies. Of 3,135 papers identified in the search, 272 papers were used in the evidence tables and the review.

Selection Criteria: For papers related to SES, selection criteria for inclusion of articles are: those papers published from 1990 through 2000 in order to reflect current economic conditions; papers prior to 1990 are excluded; studies with a sample of 100 subjects or more so that relatively reliable estimates of relationships between caries and SES can be made; English language studies; and studies that include one or more SES classification measures. Two behavioral risk factors are assessed, tooth brushing and use of the baby bottle. Studies are limited to those from 1975 forward when abstracts became available in bibliographic databases; and a minimum sample size of 25 subjects per group. Indicators for tooth brushing must include at least one of the following measures: plaque scores, calculus scores, self-reports of tooth brushing frequency. Additionally, use of fluoride tooth paste was considered. For baby bottle use, the study must include at least one of the following measures: use of a bottle past the age of 12 months, use of the bottle when putting the baby to bed at night or at nap time, frequency of bottle use during the day, contents of baby bottle (i.e., milk, juice, etc.). Data on breastfeeding are included where reported.

Main Results:

SES and Caries among Children: The quality of the evidence demonstrating a significant inverse relationship between SES and caries prevalence for children under the age of 12 is moderate, though attenuated with age. The evidence of the relationship between SES and caries prevalence for

adolescents is somewhat weaker than that for younger children. There are relatively few longitudinal studies assessing SES and its relationship to caries incidence among either children or adults. Further, many of the studies assessing caries prevalence and SES employ ecological indicators of SES restricting conclusions about SES and caries risk to broad generalizations about groups. Other weaknesses are that few studies make a distinction between pit and fissure or smooth surface caries or other caries patterns and only about half of the studies reviewed conducted multivariate analyses adjusting for confounding variables. Studies that do account for other variables do not consistently find a significant effect for indicators of SES on caries prevalence or incidence. Notably, some evidence suggests that the effects of SES on caries risk are attenuated in fluoridated communities.

The quality of evidence assessing SES and caries for adults is weak, with relatively few studies of only moderate quality, as we define quality, having been conducted. The problem of defining dental caries measures is more difficult for adults than children as the most widely used measures of caries (DMFS/T Indices and the Root Caries Index) represent years of accumulated disease. Prevalence studies that reported the number of carious lesions present are unable to provide information in terms of the length of time the lesion was present, severity of the lesion or caries activity. SES is not consistently related to caries among adults either in the bivariate or multivariate analyses reported in the studies reviewed.

***Conclusions about SES and Caries*:** Although the evidence about SES and caries risk is not consistent, there are sufficient data to conclude that individuals of lower SES measured by a variety of indicators are at greater risk of caries and of the pain and impaired quality of life that accompanies severe caries. Exactly how SES operates as a risk factor is poorly understood either in oral health or in other chronic and acute health problems. However, clinicians can employ their knowledge of patients' SES as a marker to identify high risk patients for early intervention strategies and for more intensive and more frequent preventive services.

Tooth Brushing and Caries: Although there are many of studies of tooth brushing and caries among children, the quality of these reports in aggregate is weak in that there are few longitudinal studies and only a limited number of reports present multivariate analyses. The results of the review are equivocal, in that some studies find a strong, consistent relationship between brushing and/or measures of oral hygiene and caries incidence/prevalence while other studies fail to find this association. A few studies report that increasing brushing frequency is associated with higher caries rates, most likely demonstrating a weakness of cross-sectional designs. Other variables often significantly related to caries prevalence and incidence in the tooth brushing studies include use of other forms of fluoride, regular dental visits, SES and frequency of snacking. Most participants report using fluoridated toothpaste when brushing making it difficult to differentiate the effects of plaque removal from the effects of the application of fluoride.

In contrast to the literature on children, the literature on the relationship between caries and tooth brushing among adults is quite small. Only 14 papers met the inclusion criteria for the systematic review. The quality, in the context of this review, of studies is poor. There are few longitudinal cohort studies and most studies consist of samples of convenience rather than being representative community studies. The indicators of caries, DFMS/T and RCI, are limited by being measures of a lifetime of accumulated disease. A few studies include new carious lesions and recurrent decay as caries measures, but these are in the minority. Therefore, it is not surprising that the data regarding the association between caries and tooth brushing among adults is equivocal with some studies supporting this relationship and others not demonstrating a significant relationship between caries and tooth brushing. Overall, the evidence is so limited, that no conclusions can be drawn from the existing literature other than that there is weak evidence of an inverse association between oral hygiene and root caries.

Baby Bottle Use and Caries: The quality of the 40 papers reviewed is weak and only 26% of the papers report multivariate analyses. Most of the studies are cross-sectional surveys of small samples

that rely on retrospective reports of bottle use that are subject to recall bias. The bivariate and multivariate analyses of the studies do not consistently demonstrate that prolonged bottle use or use of the bottle at bed time is related to caries risk. There is weak evidence that having sugary liquids in the bottle contents may increase caries risk.

Conclusions: There is considerable evidence that SES is related to caries risk for some ages. Those in the lower SES groups demonstrate elevated risk for caries prevalence, particularly for young children. However, the quality of the data is only moderate and the association between SES and caries risk among adults is inconsistent. Further, the studies reviewed do not provide insight into how SES influences caries risk.

Tooth brushing may have a protective effect on caries risk, although the quality of the studies particularly among adults is poor, and the effect of fluoride rather than mechanical cleansing is not clear. Recommendations about tooth brushing as a strategy in managing caries is not well supported by the literature.

The literature on baby bottle use and caries risk is weak and no recommendations can be made about either limiting bottle use to prevent caries or altering the current recommendations about prolonged bottle use or putting a child to bed with a bottle, though some caution may be warranted in the dogmatic application of these recommendations at the individual level. However, sugar supplementation of bottle contents should be discouraged pending reports to the contrary.

Recommendations: Longitudinal studies of SES and caries risk are needed, particularly among adults. This would require additional discussion of how to define caries as well as how to measure and analyze SES in a way that would provide a better understanding of how SES contributes to poor health. Likewise, longitudinal studies of tooth brushing and baby bottle use are needed to assess the role of these two behavioral risk factors in caries incidence and prevalence.

BACKGROUND AND SIGNIFICANCE

The United States Surgeon General's Report on Oral Health in America (1) describes the improvements in oral health that have taken place over the past 50 years. This is particularly evident in the dramatic declines in the prevalence and severity of dental caries reported for the period between two national oral health surveys conducted in 1979-80 and 1988-94 (1). Despite such improvements, dental caries remains the most prevalent childhood disease in the United States affecting 50% of children ages 5-9 years and 78% of 17 year olds[1]. Caries also is highly prevalent among adults with the average number of decay, missing and filled surfaces (DMFS) increasing with age from a mean of 10 DMFS for 15-24 year olds to more than 60 DMFS for 55-64 year olds to approximately 80 DMFS for those 75 years and older (1).

Improvements in oral health in the US are encouraging, however, not all segments of American society have benefited equally from the effects of fluoride on the reduction in dental caries or from improvements in dental treatment and in the prevention of oral diseases. Large disparities in oral health still exist between the wealthiest and poorest Americans[1]. Furthermore, although health disparities are generally recognized, questions remain about the underlying mechanisms that account for differences in oral health as related to socioeconomic status as well as the behavioral risk factors associated with the incidence and prevalence of dental caries throughout the lifespan (2). The purpose of this paper is to systematically evaluate the evidence in three areas: 1) the association between socioeconomic status and the incidence and prevalence of dental caries throughout life; 2) the effects of tooth brushing on the incidence and prevalence of dental caries throughout life; and 3) the use of the baby bottle in the incidence and prevalence of dental caries among young children.

The paper is organized in the following manner. First, oral health and SES is placed in the context of what is known about SES and general health, leading to a conceptual model of SES and health that can

be applied to oral health. This is followed by a discussion of SES measurements and the limitations of current measurement methodologies, in particular ecological measures of SES. Two behaviors believed to be associated with dental caries, tooth brushing and use of the baby bottle, are addressed within the context of the conceptual model. Finally, the concept of risk is discussed in order to address how this systematic review can be used to identify and manage individuals who are more likely to have caries.

Socioeconomic Status (SES) and Health

A substantial body of literature exists which documents the relationship between socioeconomic status (SES) and health (3). Most studies of acute and chronic health problems in the United States and other industrialized countries consistently find an inverse relationship between SES and the incidence and prevalence of disease: as socioeconomic status increases, disease, illness and their impacts decrease. This is especially true of health conditions related to lifestyle factors, such as cardiovascular disease and some cancers (4) as well as for infectious diseases (5). This relationship exists between SES and other measures of health status, including self-ratings of health status, disability days, health status questionnaires and health practitioner ratings (2).

Although considerable evidence exists to support the relationship between SES and health, how SES operates to influence health outcomes is poorly understood. The general living environment of the economically disadvantaged consisting of poor housing, unhealthy living conditions, violence, and unemployment all contribute to high risk of poor health status. Unhealthy lifestyle behaviors, such as smoking (6 4), poor diet (4) and lack of exercise (4), are more prevalent among lower SES groups and contribute to poor health status. Access to health care is more limited (7), as is health insurance coverage (8), which limits utilization of health services that could reduce the effects of health conditions through prevention and early interventions. How individuals who are disadvantaged perceive symptoms and act upon them may differ from how economically advantaged individuals perceive their health

needs[2] and respond to them. Limited resources among the disadvantaged are likely to act as barriers, which influence the *ability* to act upon 1) symptoms of disease, or 2) the need for preventive health services. Practitioners' responses to patients may differ across SES levels. Finally, these factors in aggregate may produce a physiologic response conducive to disease. The relationships of these factors to social-political-economic empowerment, in the context of oral health is not understood.

Figure 1 proposes a conceptual model that could explain the relationship between SES and health (2). SES as an individual constraint theoretically has both direct and indirect effects on health status. The indirect effects are those mechanisms that account for increased risk at an individual level and include those factors mentioned above such as health beliefs, attitudes and behaviors that influence risk of disease. SES also reflects social structural risks related to political or economic disenfranchisement in lower SES strata that could account for class differences in health beliefs and behaviors. For example, individuals of lower SES may have experienced significant access barriers to health care facilities and as a result no longer seek or have the opportunity to seek health care for preventable conditions.

The direct effects of SES on health status not accounted for by individual level variables, health care delivery factors or the environment present a major challenge to investigators as they attempt to identify how SES operates to influence health. Some authors suggest that the direct effects of SES on health status are the result of accumulated disadvantage over the lifespan (9). Others theorize that the effects of psychological stress associated with these social locations contribute to both poor mental and physical health status among the disadvantaged (10). More studies are needed to specify these relationships.

Defining and Measuring SES

Defining SES is more difficult than it first appears. It is an abstract and complex construct that represents how *power and resources* are distributed in society (11). In contemporary society and in

developed countries, SES generally is measured by indicators of human capital, such as income, education or occupational prestige that offer advantages to those individuals and their families (11). Social status relationships of these factors may vary within and between cultures and ethnic groups in and across countries.

Another approach to measuring SES is to assign a social status position based on ecological measures (12) derived from place of residence. For example, the Townsend Index (13) is a measure of social deprivation used in studies in Great Britain based on housing, car ownership, etc., within a census district or voting ward. This measure is assigned to the individual. The potential ecological fallacy is that the social deprivation evident within the social environment where the individual resides may not apply to every person. This may not only weaken the potential relationship between SES and health or other social outcomes, but could lead to conclusions about individuals that are valid only at an aggregate societal level, that is, these measures are of the "neighborhood" SES environment

Both individual self-reported measures of SES and ecological measures are used in this analysis to assess the relationship between SES and caries incidence and prevalence. These include measures of occupational prestige such as those used in British classification systems (14), education, income and indicators of poverty, as well as measures that employ weighted measures of social class based on models that incorporate education, occupation and/or income. Ecological measures such as the Townsend Deprivation Index and others like it, such as the Jarmen Scale (15) or ACORN (16), are considered acceptable ecological measures of SES. However, studies employing ecological measures will be considered of less quality than those employing self-reported measures of SES. Other indicators of SES include enrollment in a needs-based program such as Medicaid or Head Start, school lunch programs, and income expressed as a percentage of the poverty level.

The conceptual model of SES and health can be applied to oral health and dental caries as shown in Figure 2. The model hypothesizes both direct and indirect effects of SES on the incidence and prevalence of dental caries. For this paper, analysis of the indirect effects of SES on oral health is limited to two behaviors, tooth brushing and feeding practices.

Dental Caries and Tooth Brushing

Tooth brushing with a fluoride dentifrice is generally regarded as an effective method of preventing dental caries (17). In Figure 2, tooth brushing is a behavior that could moderate or mediate the relationship between socioeconomic status and caries incidence and prevalence. This part of the review will analyze how both self-reported measures of tooth brushing and/or measures of clinical oral hygiene are related to caries prevalence and incidence. Self-reported measures of tooth brushing generally include daily frequency of tooth brushing. Clinical indicators of oral hygiene as a measure of brushing quality or a proxy for brushing frequency consist of measures of plaque on either all the teeth or a select number of indicator teeth (18 19).

Infant Feeding Practices

The American Academy of Pediatric Dentistry recommends that children should be weaned from the bottle or breast by age 12 months and that children should not be put to bed with a bottle (20) that contains liquids other than water. This recommendation is based on the belief that prolonged use of the baby bottle or breast feeding past 12 months, over use of the baby bottle or demand breast feeding of the baby during waking hours or putting an infant to bed with bottle that contains milk, formula or juice, are the underlying causes of anterior maxillary caries. A recent review of the psychosocial factors and early childhood caries (21) finds that use of a bottle at bedtime is highly prevalent among children with and without caries and that there is little evidence to substantiate the belief that use of the bottle or breast feeding beyond the age of one is a major caries risk factor. The role of feeding practices in the etiology

of caries among young children is not well understood, although it is generally accepted that feeding practices have some role in the *multifactorial* process resulting in caries among young children.

Defining inappropriate infant feeding practices and identifying suitable indicators for these behaviors presents a challenge. This review focuses on how caregivers use the baby bottle and its relationship to caries incidence and prevalence. The following indicators of baby bottle use are included (21 22): age at weaning or duration of bottle use, frequency of bottle use, putting the baby to bed with a bottle and contents of the baby bottle. Data on breast feeding and sugar intake will be collected and presented in the evidence tables, as well

The Concept of Risk

This paper evaluates three variables that are considered risk factors for the incidence and prevalence of dental caries. Because of ethical and practical reasons, there are no randomized clinical trials of SES and caries and few randomized trials of tooth brushing and baby bottle use. Epidemiological methods in population-based research can be used to study how biological, social, behavioral and environmental factors influence risk of developing a disease, health condition or death. Risk is the "probability that a specified event will occur (23)." For the purposes of this paper, risk refers to the probability of a person developing caries in a specified period of time or at a specified age. Analytical studies in epidemiology have the ultimate aim of identifying cause and effect relationships. However, likely causality can only be demonstrated with randomized clinical trials, which in certain contexts are not possible, such as the SES question being addressed here. Epidemiological methods can be applied to research questions to assess how a risk factor, defined as an attribute (such as SES) or an exposure (tooth brushing or baby bottle use), is associated with increased probability of a disease occurrence, a body of such reports suggesting possible causality. Burt and Ecklund (23) have put forth three criteria for a given attribute or behavior to be considered a risk factor for a given disease state: "the exposure must co-vary with the

disease, meaning that the frequency of the disease must be observed to differ by category or value of the exposure; the exposure must precede the occurrence; the observed association must not be the result of error." Beck and colleagues (24) have proposed a supplementary concept of determining risk in population studies that recognizes apparent risk factors as possible "markers" of underlying causal factor(s). In this report, SES, toothbrushing and bottle feeding may be protective/risk factors per se, or markers of associated factors that are truly protective/risks and not addressed in the analyses reviewed.

Summary and Objectives

As previously stated, the Surgeon General's report and other reviews (2 22 25 26) conclude that SES is significantly related to oral health, with those in the lower segments of society being at greatest disadvantage. This premise holds for caries incidence and prevalence among both children and adults. However, no systematic reviews of these relationships have been conducted and these premises are based largely on selective reviews of the literature. This paper advances the literature in the area by systematically selecting papers for inclusion in the review based on pre-established criteria, evaluating the quality of the papers reviewed and synthesizing results based on these studies. Additionally, this paper evaluates the literature on the importance of two behavioral risk factors that may contribute to the explanation of SES differences in the risk of caries, tooth brushing and infant feeding practices.

Improved management of caries among children and adults is the primary objective of this analysis. Results from this review can be used to evaluate how SES operates as a risk factor for caries and how knowledge of this risk factor can influence management of disease. Additionally, the results will be the basis for setting an agenda for research on how to measure and evaluate SES and to intervene to reduce the effects of SES on caries incidence and prevalence. Finally, results on the importance of tooth

brushing and infant feeding practices in caries risk can be integrated into a evidence based approach to anticipatory guidance and the clinical management of caries.

Key Questions

The key questions were developed by the authors then reviewed by staff at NIDCR. All questions as well as inclusion/exclusion criteria for paper selection were assessed at a two-day meeting in July, 2000 of the panel of authors presenting papers at the caries consensus conference. Nineteen authors and co-authors attended this two day meeting. Minor revisions were made to the wording and intent of the questions. The selection criteria for papers relating to SES and caries originally restricted inclusion of papers to studies conducted in the United States because of their greater relevance to the American health system and socio-political economy. Based on an extensive discussion at this meeting, the inclusion/exclusion criteria were revised to include international studies as well. For questions related to SES, the panel agreed that limiting the review to papers published since 1990 would better reflect contemporary economic conditions. For questions related to tooth brushing and baby bottle us, eligible papers would include those published since 1975 when abstracts became available in bibliographical databases. Eight questions are addressed in the review:

1. Are children less than six years of age with primary teeth and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status ?

2. Are children ages six to 11 with mixed dentition and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status ?

3. Are children ages 12-17 with permanent teeth and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status ?

4. Are adults ages 18-64 and of lower socioeconomic status at increased risk of dental caries compared with adults of the same age of higher socioeconomic status ?

5. Are adults ages 65 and older and of lower socioeconomic status at increased risk of dental caries compared with adults of the same age of higher socioeconomic status ?

6. Are children ages less than 18 who do not brush their teeth one or more times daily at increased risk of dental caries compared with children of the same age who do brush?

7. Are adults ages 18 and over who do not brush their teeth one or more times daily at increased risk of dental caries compared with adults of the same age who do brush?

8. Are children over the age of 12 months who continue to use a baby bottle once or more a day at increased risk of dental caries compared with children of the same age who no longer use a baby bottle?

METHODS

This section describes the inclusion and exclusion criteria, the methods used to search the literature and select papers, data abstraction and the variables in the evidence tables and the quality ratings used to assess the studies.

Inclusion/Exclusion Criteria for Articles

Specific inclusion/exclusion criteria for articles identified in the literature search are presented in outline form below. As previously mentioned, for papers related to SES (questions 1-5), selection of articles is limited to those papers published in 1990 or after because of the belief that the worldwide economy has changed rapidly over the past ten years, occupational structures in both developing and Western industrialized countries have evolved to include many new industries that make older studies of SES of less relevance to contemporary society and educational attainment has increased such that comparisons to SES structures that existed even ten years ago may not be comparable to studies conducted today. Because studies of relevance to SES will consist mostly of community based population surveys rather than randomized clinical trials, study selection is limited to those with a sample of 100 subjects or more so that relatively reliable estimates of relationships between caries and SES can be made. Only English language studies are included in this study due to resource limitations. One limitation of many studies of the effects of SES and oral health is that samples consist of only individuals from disadvantaged social strata making comparisons to advantaged groups impossible. For example, many studies of Head Start children or those recruited from Medicaid populations demonstrate high levels of caries among these individuals, yet conclusions about their relative risk is impossible because of lack of a comparison group. Studies for this review are limited to those that include more than one SES classification level and must have at least one indicator of SES as shown below. Finally, studies must have an accepted indicator of caries incidence or prevalence as shown below. Studies that include only measures of tooth loss or rates of edentulism are excluded.

Papers related to behavioral risk factors are limited to two behaviors, tooth brushing and use of the baby bottle. Papers for these studies are limited to those from 1975 forward when abstracts for papers became available on bibliographical databases. Because studies included in these reports could potentially include randomized clinical trials, the sample size criterion was set to 25 subjects per group, again, so

that relatively stable estimates of the effects of these behaviors could be made. As previously discussed, indicators for tooth brushing must include at least one of the following measures: plaque scores, calculus scores, self-reports of tooth brushing frequency, use of fluoride tooth paste. For baby bottle use, the study must include at least one of the following measures: use of a bottle past the age of 12 months, use of the bottle when putting the baby to bed at night or at nap time, frequency of bottle use during the day, contents of baby bottle (ie, milk, juice, etc.). Data on breastfeeding will be included where reported. Studies must include at least two groups at two differing levels of behavior in order to compare the effects of these levels on caries risk. For example, those brushing once a day compared to those brushing less than once a day.

Specific inclusion/exclusion criteria for each area are as follows:

I. Socioeconomic (SES) Risk Factors for Dental Caries (Questions 1-5)

A. Inclusion Criteria

1. Time Period: Articles published 1990 or after because of the changing economy in the US
2. Sample Size: Include only articles that have a minimum sample of 100
3. SES: Include only articles that have one or more of the following indicators of socioeconomic status: education completed, total family income in the past year, occupation, poverty status, Medicaid recipient, eligible for Head Start, eligible for WIC. In the case of children, these variables would apply to the head of household.
4. Language: English language papers only.
5. SES Comparison Groups: There must be at least two groups in different socioeconomic strata. For example, high income groups compared to low income groups; Head Start children compared to non-Head Start Children.
6. Caries Measures: One or more of the following measures of caries must be present: percent of the sample that is caries free, dmft/s, DMFT/S, Early Childhood caries defined as the presence of decay on one or more of maxillary anterior teeth among children less than 3 years of age (27).

B. Exclusion Criteria

1. Time Period: Articles published prior1990
2. Sample Size: less than 100
3. SES: Studies that do not have one or more of the following indicators of socioeconomic status: education completed, total family income in the past year, occupation, poverty status, Medicaid recipient, eligible for Head Start, eligible for WIC. In the case of children, these variables would apply to the head of household.
4. Language: Non -English language papers.
5. SES Comparison Groups: Studies that include only one SES group

II. Behavioral Determinants as Risk Factors for Dental Caries (Questions 6-8)

A. Inclusion Criteria

1. Time Period: Articles published 1975 or after
2. Sample Size: Include only articles that have a minimum sample of 25 in each group
3. Behavioral Determinants:
   a. Oral Hygiene: Studies must include at least one of the following measures: plaque scores, calculus scores, self-reports of tooth brushing frequency, use of fluoride tooth paste
   b. Baby Bottle Use: Study must include at least one of the following measures: use of a bottle past the age of 12 months, use of the bottle when putting the baby to bed at night or at nap time, frequency of bottle use during the day, contents of baby bottle (ie, milk, juice, etc.)
4. Language: English language papers only.
5. Behavioral Comparison Groups: There must be at least two groups in different behaviors. For example, those who brush their teeth less than once a day compared to those who brush more than once a day.
6. Caries Measures: One or more of the following measures of caries must be present: percent of the sample that is caries free, dmft/s, DMFT/S, Early Childhood caries defined as the presence of decay on maxillary anterior teeth among children less than 3 years of age.

B. Exclusion Criteria

1. Time Period: Articles published prior1975
2. Sample Size: less than 50 (25 in each group)
3. Language: Non -English language papers.
4. Behavioral Comparison Groups: Studies that include only one group

Searching the Literature and Selecting Papers

A consultant was contracted by NIDCR to construct the search terms and to search the literature in two databases, Medline and EmBase. Search terms and the resulting number of abstracts at each step of the limitations are shown in the appendix for each question. The consultant also was provided with 2-3 citations for key articles that should be included in the literature searches to assure that the searches captured relevant studies. Because of limitations in resources, we did not conduct hand searching or search unpublished studies. This is a limitation of the review in that it is possible that only studies demonstrating significant effects for the risk factors of interest are generally published. The review may have a bias towards supporting significant relationships between SES, tooth brushing and use of the baby bottle and caries.

The consultant initially developed a search strategy for all the reviews in the conference (called a "hedge") that identified all the studies that related to caries in the two databases. This initial search provided the basis for subsequent searches limited for this review related to SES, tooth brushing and baby bottle use and caries. Table 1 presents for each question the total number of papers identified in the initial search of Medline and EmBase, the number selected in for initial review by the authors, and the final number of papers included in the evidence tables.

Both authors reviewed all abstracts for inclusion; complete papers were reviewed either when no abstracts were available or when the abstracts did not include sufficient information to evaluate them according to the inclusion/exclusion criteria. Disagreements were resolved through discussion and consensus of the two authors. Following selection, all papers meeting the inclusion criteria were requested from the UCHC library; those not available locally were requested through interlibrary loan. Eighty-six papers were deleted during the review process if they did not have a caries measure or an indicator of SES, tooth brushing or bottle use or because they could not be located through the library. This process resulted in a total of 272 papers being included in the systematic review.

Data Abstraction and Variables in the Evidence Tables

The authors discussed and agreed upon the variables to be included in the evidence tables. The evidence tables include information about the year, first author, type of study, recruitment, response rate, sample size, training of the investigators, reliability, caries diagnostic criteria, caries measures, measures of SES, tooth brushing and bottle use, control variables, the major bivariate and multivariate results and a summary of the findings. There are eight evidence tables, one for each question followed by a reference list. The numbers next to the author's name refer to the citation for the reference list for that table. There is some redundancy in the tables as some papers are included in more than one evidence table

because of an overlap in age groups. This was done in order to evaluate relevant evidence separately for each question.

Data from the papers were abstracted directly from the papers into an ACCESS data base without use of a data abstraction form. The first author (SR) abstracted the data from all the papers into the database. For quality control, the second author (WP) independently reviewed the tables and conducted a 10% reliability check of the data abstracted from the papers in the tables.

Additionally, the second author (WP) evaluated three review articles (28 29 30) identified in the search for each specific question to assure that the search did not miss any relevant papers. We compared the citations in the review papers with this project's references. The three reviews consisted of 16, 4 and 11 references, respectively, that met this project's inclusion criteria. Watt and Sheiham (29) cover aspects of oral health other than caries, and cite a large number of official reports rather than peer review published studies.

Twenty-seven (87%) of the 31 applicable review paper citations were identified in the literature searches conducted for this project; 13 of the 27 reports were included in the final evidence tables with 14 excluded. Notably, only 2 of the 4 articles not identified in this project's search met the inclusion criteria on further examination. Wendt (30) was assessed for citations by the topics of SES, tooth brushing and infant feeding. Four (36%) of the citations identified by specific topics in Wendt's report were not identified in the topic specific searches of this project although these four reports were identified in other of the project's topic searches.

The results of this reliability evaluation suggest that our search achieved a comprehensive identification of pertinent published studies. However, reports that may have applicability to several questions posed by this project may not have been identified for each specific question.

Quality Ratings of the Studies

The quality rating scales used for Questions 1-5, 6-7 and 8 are shown in Table 2 and contain scoring values for study design (1-5), recruitment method (0-2), response rate at baseline (0-2), response rate at follow-up for longitudinal studies (0-2), training of examiners (0-2), reliability (0-2), caries diagnostic criteria (0-1), measures of SES (for questions 1-5; 1-2), measures of tooth brushing (for questions 6-7; 1-2) and measures of baby bottle use (for questions 8: frequency of feeding (0-1); baby to bed at bed time (0-1); information about contents of the bottle (0-1); age at weaning or duration of bottle use (0-1); information about breastfeeding (0-1), adjustment for confounders (0-1). The quality scores for questions 1-5 could range from 1-19; for questions 6-7 the quality scores range is 1-19; and for question 8 the scores range is 1-22.

RESULTS

This section describes the results of data abstraction into the evidence tables, the quality ratings and evaluation of the evidence for each table.

Question 1. Are children less than six years of age with primary teeth and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status ?

Forty-six papers meet the criteria for inclusion in the review for this question. The quality of the papers reviewed is relatively weak as shown in Table 3, with a mean score of 8.8 (sd=2.7) out of a possible total score of 19. Table 4 shows that the studies are primarily cross-sectional surveys of associations

between SES and caries prevalence or ecological studies of these associations that assign aggregated measures of social deprivation to individual participants. There are relatively few longitudinal or case-control studies that assess the relationship between SES and the *incidence* of caries among young children. Further, the measures of caries prevalence and incidence consist either of the presence of caries, dmfs/t or a measure of rampant caries. Few if any studies assess patterns of caries prevalence and progression, although some studies do assess proximal caries rates. The diagnostic criteria used to assess caries and to develop the dmfs/t measures vary considerably across studies, making comparisons across studies difficult. Finally, for purposes of this consensus panel, relatively few studies of SES and caries have been conducted in the United States. Therefore, caution should be exercised in generalizing the findings from other countries to the United States as interpretation of SES indicators can vary by cultural context.

Review of the bivariate analysis of caries prevalence and SES indicators (see columns titled Prevalence of Caries and Summary, Table 4) demonstrates a fairly consistent significant inverse relationship between caries prevalence and SES: children in families of low SES compared to children in families with high SES have higher prevalence of caries. When the effects of other variables are analyzed, the inverse relationship between SES and caries prevalence in this age group largely remains significant in the studies that report multivariate analyses. Interestingly, and importantly, for a discussion of optimum fluoride levels, several studies in Table 4 (31, 32, 33, 34) report that the effects of SES on caries prevalence are attenuated in areas that have fluoridated water. Despite the study weaknesses, the preponderance and consistency of the inverse relationship between SES and caries, considered in aggregate, are supportive of lower SES levels being a risk factor for dental caries for young children.

Are children ages six to 11 with mixed dentition and of lower socioeconomic status at increase risk of dental caries compared with children of the same age and dentition of higher socioeconomic status ?

Forty-five papers were reviewed for this question. The quality of the studies for this age group is somewhat better than the studies that include younger children with a mean quality score of 9.2 (sd=3.4) of a possible total of 19, and more than half of the studies include some type of multivariate analysis. More reports were of studies conducted in the US (n=15) in this age group than identified for younger children. A limitation of the studies is that the vast majority are cross-sectional surveys or ecological studies. The dependent variables assessed consist of dmfs/t, DMFS/T and the percent caries free defined by having a caries index of less than 1. The studies rarely make a distinction between pit and fissure caries or smooth surface caries.

The bivariate analyses in these studies consistently find a significant inverse relationship between indicators of SES and caries prevalence. Papers that report multivariate analyses primarily demonstrate that SES is still related to caries prevalence when other variables are controlled in the analyses (35, 36, 37, 38, 39, 40, 41, 42, 43, 44), but this is not consistently found across studies studies (45, 46, 47, 48, 49, 50, 51, 52). Although the quality of the papers is not strong, the evidence does suggest that there is a strong relationship between SES and caries prevalence in children in this age group.

Are children ages 12-17 with permanent teeth and of lower socioeconomic status at increased risk of dental caries compared with children of the same age and dentition of higher socioeconomic status ?

There are only 15 papers that meet the inclusion criteria and that address the relationship between caries and SES in this age group. The total number of abstracts identified (n=287) through the search is relatively low compared to the other age groups. The information about SES and caries in this age

group is fairly limited and the studies are primarily cross-sectional surveys or ecological studies. Only four studies are based in the United States. Several of the studies do not support a significant relationship between SES and caries prevalence at the bivariate level (53, 51), although with the exception of Vargas (47) and Dummer (51) the multivariate analyses reported in seven papers show that SES largely remains a significant factor in explaining caries levels. The quality of evidence supporting the inverse relationship between SES and caries in this age group is relatively weak because of the small number of studies, the few studies conducted in the United States, the lack of adjustment in the analyses for confounders and the moderate mean quality rating of the studies with a mean of 8.6 (sd=2.5).

Are adults ages 18-64 and of lower socioeconomic status at increased risk of dental caries compared with adults of the same age of higher socioeconomic status ?

Twenty-four papers are included in the evidence table for this question. Considering the large age range in this age group, it is surprising that more surveys of adults and the effects of SES on caries have not been conducted. Most studies have cross-sectional survey designs and few are ecological studies. The overall quality of the studies is somewhat but not substantially better than other studies of SES and caries with a mean score of 9. 5 (sd=2.9), with more than half having some form of multivariate analyses adjusting for confounders. The data in the evidence tables suggest that the relationship between SES and caries prevalence is not as strong as is found for children. The bivariate analyses do not consistently show a significant relationship between SES and caries and multivariate analyses are inconsistent, as well, with some studies finding a significant inverse relationship (54, 55, 56, 57) and others reporting that SES is not significantly related to caries (58, 59, 60) when other variables are controlled.

Are adults ages 65 and older and of lower socioeconomic status at increased risk of dental caries compared with adults of the same age of higher socioeconomic status ?

Fourteen studies are included in the evidence table for this question. This age group has smallest number of abstracts identified for the review (n=190) indicative of a relative lack of studies among older adults. As with younger adults, the evidence for evaluating the relationship between SES and caries is weak. The quality rating is moderate with a mean of 8.9 (sd = 3.4), but this is because there are no ecological studies and there are more longitudinal studies that increase the overall score. There are more studies conducted in the US, but three papers are based on the same study of a North Carolina sample. As with younger adults, the relationship between indicators of SES and caries prevalence and incidence is not consistently supported in these studies either in the bivariate or multivariate analyses but in aggregate the reports suggest an inverse relationship between SES and caries prevalence in this age group, in particular, in terms of root caries.

Summary of Findings for SES and Caries

The quality of the evidence demonstrating a significant inverse relationship between SES for children is moderate but for adolescents the evidence is equivocal. There are relatively few longitudinal studies assessing SES and its relationship to caries incidence, and many of the studies assessing caries prevalence and SES cross-sectionally employ ecological indicators of SES. The bivariate analyses of studies among younger children, particularly children less than 6 years old, strongly support an inverse relationship between SES and caries prevalence measured by dmfs/t or DMFS/T indices, but few studies make a distinction between occlusal or smooth surface caries.

About half of the studies reviewed conducted multivariate analyses adjusting for some potential confounding variables and these analyses are less consistent in finding a significant effect for indicators of SES on caries prevalence. Evidence suggests that the effects of SES on caries are attenuated in fluoridated communities.

The quality of evidence assessing SES and caries for adults is even weaker than in the younger age groups, with fewer total numbers of studies of only moderate quality. The problem of defining caries is more difficult for adults than children as the most widely used measures of caries (DMFS/T Indices and the Root Caries Index) represent years of accumulated disease. A further limitation of these indices is that the missing tooth component of DMFS/T may be the result of periodontal disease or trauma and be unrelated to caries. SES is not consistently related to caries among adults either in the bivariate or multivariate analyses reported in the studies reviewed.

SES as a Risk Factor

As Beck and others (24 61) suggest SES may be both a *marker* of risk, representing other attitudinal, behavioral variables and health care delivery system variables, that directly influence the prevalence and incidence of caries or SES may have direct effects on developing caries. That is, SES may be considered a proximal risk factor "causing" rather than "marking" more distal risk factors or a differential distribution of these factors. The data on the relationship between caries and SES among adolescents and adults is inconsistent, but suggests that being in a lower SES level is a risk factor for caries although the underlying mechanisms may not be accurately specified. Although our understanding of how SES affects the caries process remains poor, it seems that SES is a critical variable in targeting health promotion and disease prevention programs at the individual and community levels because caries is more likely to be observed among those in lower SES strata regardless of how SES is measured – at the individual, family or ecological level.

Tooth Brushing and Caries

Are children ages less than 18 who do not brush their teeth one or more times daily at increased risk of dental caries compared with children of the same age who do brush their teeth one or more times a day?

There is a fairly large literature identified in the initial search that investigates the effects of tooth brushing on caries risk. More than 800 papers were identified as being published since 1975 that address this question in some form for children less than 18 years of age. Of these papers, 93 were selected for inclusion in the review with a final number of 72 papers being entered in the evidence table. The overall quality rating for the studies is weak with a mean score of 8.6 (sd=2.5) although only about half of the studies include a multivariate analysis. The results of the review are equivocal, in that some studies find a strong, consistent relationship between brushing and/or measures of oral hygiene and caries incidence/prevalence while other studies do not find this association. Some studies report that more brushing is associated with higher caries rates.

The results of multivariate analyses where available also are inconsistent with some studies reporting a significant reduction in caries risk associated with brushing frequency or clinical oral hygiene measures and other studies showing that brushing does not have a significant effect on caries when other factors are controlled for. Other variables that often are significantly related to caries prevalence and incidence in the studies reviewed include use of other forms of fluoride (such as mouth rinses and fluoride tablets), regular dental visits, SES, total sugar consumption and frequency of snacking. Overall, there is evidence of a weak relationship between tooth brushing and decreased dental caries.

The most frequently reported indicator of tooth brushing is either self-reported frequency of brushing or parental reports of brushing frequency. Almost all of the studies report that teeth were brushed with a

fluoride dentifrice; several of the studies were clinical trials of varying levels of fluoride concentration or type of fluoride preparation. It is therefore difficult to distinguish whether the effect of tooth brushing is actually a measure of fluoride application or whether it is the result of mechanical removal of the plaque.

Studies that employ clinical measures of plaque levels, such as the Silness and Loe plaque score or the Greene and Vermillion OHI-S, also show that good oral hygiene is associated with lower prevalence and incidence of caries. Again, it is not clear whether the effect of optimal oral hygiene practices on caries reductions is the effect of plaque removal or the application of fluoride through the use of fluoride dentifrice.

Are adults ages 18 and over who do not brush their teeth one or more times daily at increased risk of dental caries compared with adults of the same age who do brush their teeth one or more times daily?

In contrast to the literature on children, the literature on the relationship between caries and tooth brushing among adults is quite small. Only 334 studies were identified in the search and only 14 papers met the inclusion criteria for the systematic review. The quality of studies is similar to studies in the other questions, with a mean quality score of 8.3 (sd=1.7) of a possible score of 19. There are few longitudinal cohort studies and most studies consist of samples of convenience rather than being representative community studies. The indicators of caries, DFMS/T and Root Caries Index (RCI), are limited by being measures of accumulated disease. A few studies include new carious lesions and recurrent decay as caries measures, but these are in the minority. Therefore, it is not surprising that the data regarding the association between caries and tooth brushing among adults are equivocal with some studies supporting this relationship and others failing to demonstrating a significant relationship between

caries and tooth brushing. Overall, the evidence is so limited, that no conclusions can be drawn from the existing literature, although the literature does provide some weak evidence of an inverse association between oral hygiene and root caries.

Tooth Brushing as a Risk Factor

Review of the evidence tables suggest that tooth brushing reduces the risk of caries for those who brush at least once a day with a fluoride tooth paste. Additionally, the evidence indicates that those with good oral hygiene measured by plaque indices are at reduced risk of caries prevalence and incidence. It is unclear whether the effect of hygiene practices is the result of increased fluoride application because of more frequent and effective tooth brushing or whether the effect is because of plaque removal. Tooth brushing and good oral hygiene practices also may be a marker for other factors that contribute to the caries process. Tooth brushing could represent cultural beliefs and norms about oral hygiene, social class factors, nutritional variables or health services utilization practices. For example, individuals who have good oral hygiene may visit the dentist more frequently resulting in fewer carious lesions.

Are children over the age of 12 months who continue to use a baby bottle once or more a day at increased risk of dental caries compared with children of the same age who no longer use a baby bottle?

Three hundred seventy papers were identified in the search, with 53 papers reviewed and 42 papers selected for the final evidence table. The quality of the papers reviewed is weak with an average score of 8.3 of a total 22 (sd=2.3); only *26%* of the papers report multivariate analyses. Surprisingly, more recent studies do not conduct analyses that adjust for confounding variables, such as sugar intake, presence of fluoridation or use of fluoride tablets. Most studies are cross-sectional surveys that rely on retrospective reports of bottle use that are subject to recall biases. Finally, the majority of studies consist of samples of convenience recruited in dental practices, health clinics or day care centers.

As a result of the weaknesses in the research designs of the studies, the bivariate and multivariate analyses presented in the evidence tables do not consistently demonstrate that prolonged bottle use, use of the bottle at bed time or that the contents of the bottle significantly affect caries risk. Because the evidence is inconsistent, no strong conclusions can be made about feeding practices and caries risk. A closer examination of the studies that employ a longitudinal design(62, 63, 64, 65, 66) find that duration of bottle is not significantly related to caries risk, but that contents of the bottle, such as milk with sugar or juice, increase the risk of caries. However, only one study was conducted in the United States (65) and that paper included previous caries in the analysis which may have obscured the importance of the baby bottle in initial caries risk.

Studies that include larger samples of greater than 500 children(30, 67, 68, 69, 70, 71, 72, 73) do not reveal consistent findings. Moynihan (69) conducted a large cross-sectional survey using multi-stage random sample design to be representative of 1-5 year olds in Great Britain. The multivariate analysis

did not find a significant effect for duration of bottle use, but having sugary drinks significantly increased risk of caries in this age group. Results from Ye (67) and Holt (73) agree that neither duration of bottle use nor contents of the bottle affect caries risk. In contrast, other large studies (68, 71, 72) find that duration of bottle use is a significant risk factor.

Babeely (74) used an interesting approach to measuring risk associated with feeding practices in that he developed a feeding abuse score based on number of feedings, bed time use and duration of bottle use. The score was significantly associated with nursing caries syndrome among 86 children in Kuwait recruited from private practices. Children with a higher feeding abuse score had more caries. The concept of constructing an additive scale to assess risk is innovative, but few other investigators have adopted this approach and Babeely's study has design weaknesses that limit generalization of these results.

LIMITATIONS

Several factors evident in the search and the reviewed studies limit the quality and generalizability of the systematic review and the conclusions that can be drawn from the review as follows:

1) The literature search was conducted solely through databases and no hand searches were conducted. This search approach may have limited the inclusion of pertinent reports, as identification of studies was dependent on MESH terms.
2) Inclusion/exclusion of reports was based primarily on assessment of the information provided in the abstracts. Therefore, the process of selecting studies for the review was subject to the quality and the content of the abstracts, which may have resulted in exclusion of relevant studies.
3) There were substantial restrictions in resources in terms of both time and financial support for this review. Time and financial constraints may have limited the comprehensiveness of the review.

4) Measurement of the variables of interest present a variety of methodological problems, including validity and reliability of the indicators:
    a) SES classification is assessed at multiple levels, i.e. individual, family and geographic (neighborhood) levels. These different levels of SES may have different associations with disease outcomes. Further, they are prone to misclassification error, are time-dependent, and may have different disease associations, depending on gender and ethnicity.
    b) Tooth brushing assessment may be a *marker* for other risk factors rather than being a risk itself. Further, the potential for misclassification of tooth brushing levels is substantial as current self-reports of tooth brushing may not accurately measure tooth brushing levels at the time the carious lesion was initiated or during the period of lesion progression
    c) Assessment of feeding practices present several methodological difficulties, including recall bias, social desirability bias, as well as being sensitive to cultural influences on normative behaviors. Additionally, lack of consensus regarding case definitions, the problem of multifactorial and multistage causality, and uncertainties about the temporal ascertainment of disease and risk factors may preclude relatively simple assessment disease and exposures.
5) The multifactorial nature of disease process makes multivariate analyses an absolute requirement in caries studies. However, a substantial proportion of studies, even those conducted fairly recently, present simple bivariate analyses and do not include more sophisticated analytical techniques currently available.

CONCLUSIONS

Socioeconomic Status and Caries Risk

There is considerable evidence that SES is related to caries risk. Those in the lower SES groups demonstrate elevated risk for caries prevalence, particularly for young children. However, the quality of the studies is not strong (as we have defined comparative quality) and the association between SES and caries risk among adults and adolescents is inconsistent. Further, the studies reviewed do not provide

insight into the etiology of how SES influences caries risk. Importantly, the protective effect of water fluoride levels appears greater in lower SES populations.

Tooth Brushing and Caries Risk

Tooth brushing with fluoride toothpaste seems to have a preventive effect on caries risk, although the quality of the studies particularly among adults is poor. Recommendations about tooth brushing as a strategy in managing caries is not well supported by the literature, but even though the evidence is not strong, more frequent tooth brushing with a fluoride dentifrice and good oral hygiene seems to be associated with a reduced caries risk.

Baby Bottle Use and Caries Risk

The literature on baby bottle use and caries risk is weak and no recommendations can be made about either limiting bottle use to prevent caries or altering the current recommendations about prolonged bottle use or putting a child to bed with a bottle. However, even though the data are not consistent, prolonged use of the bottle and putting sugary liquids in the bottle seems to play a role in a *multifactorial* process that puts some young children at increased risk of caries.

RECOMMENDATIONS

Socioeconomic Status and Caries Risk

Longitudinal studies of SES and caries risk in the United States are needed, particularly among adults, in order to assess how SES influence the incidence of disease. Much of what is known about SES and caries risk in the US is based on NHANES studies, which are cross-sectional surveys and cannot address predictors of risk and caries measures are generally prevalence measures representing long-term accumulation of disease. The few other large longitudinal epidemiological studies of caries risk factors were conducted more than 10 years ago. A general problem in the literature, particularly when

including international studies, is the lack of consensus on measures of caries. Further discussion of appropriate measures of caries for children with primary and permanent teeth and especially for adults is needed.

Another limitation of the literature is lack of consensus on how to measure SES in a way that would provide a better understanding of how SES contributes to poor oral health. The current methodology relies on measures that are static, such as educational achievement, or geographical measures that are subject to the ecological fallacy. In addition to accepted measures of SES, future studies should include variables that would provide opportunities for effective interventions to reduce risk. Interestingly, the effects of SES on caries risk seem to be reduced in fluoridated communities. This observation provides evidence that a scientifically sound, broad based community approach to caries prevention and risk reduction is effective in countering SES-based caries risks. Other factors that may be important are access to quality dental and medical care or availability of effective school based programs.

Finally, although the underlying mechanisms may not be well understood, low SES may serve clinicians as marker for increased risk of caries. Individuals of lower SES may benefit from more intensive and more frequent preventive services as well as more intensive efforts at education and health promotion activities.

Tooth Brushing and Caries Risk

Longitudinal studies of tooth brushing are needed to understand the role of tooth brushing in caries prevention, particularly among adults. The most common measure of tooth brushing is frequency per day. Relatively little is known about the importance of time of day, duration of brushing or effectiveness of brushing. Some studies that include clinical measures of oral hygiene suggest that good oral hygiene, representing not just frequency of brushing but also effectiveness of brushing, are

associated with reduced caries risk. Appropriate multivariate analyses that consider oral hygiene as a surrogate for risk/preventive factors other than tooth brushing, would have utility in answering this question.

Baby Bottle Use and Caries Risk

As previously stated, longitudinal studies with representative samples are needed. Many of the studies in the literature rely on samples of convenience and retrospective reports of weaning to evaluate the relationship between feeding practices and caries risk. Analysis of all aspects of feeding practices among young children is needed to accurately evaluate the importance of bottle use in the risk for caries. For example, some studies only assess age at weaning but not use of the bottle at bedtime or contents of the bottle. Further, risk of caries may be sensitive to an interaction between tooth eruption patterns and bottle use, its contents and other dietary practices. Finally, several additional factors should be considered when applying the results of analyses of early childhood caries as a multifactorial process, including the quality of the mother-child relationship, nutrition as a component in systemic health, and the family's confidence in the health care practitioners.

Statistical Methodologies

It is generally agreed that the caries disease process involves host, environment and agent variables. Such a conceptual approach would require multi-level, multivariate analyses and the possible need for hierarchical and robust modeling. Although this review was limited to sample sizes of 100 or greater, many of the studies reviewed had insufficient power, limiting the interpretation of negative results and possibly resulting in the weak or contradictory results observed in this review.

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